The development of manganese dioxide material as a catalyst for the ozone removal

Ketmanee Muangchan and Chamnan Randorn
Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

FACULTY OF SCIENCE
CHIANG MAI UNIVERSITY

Abstract

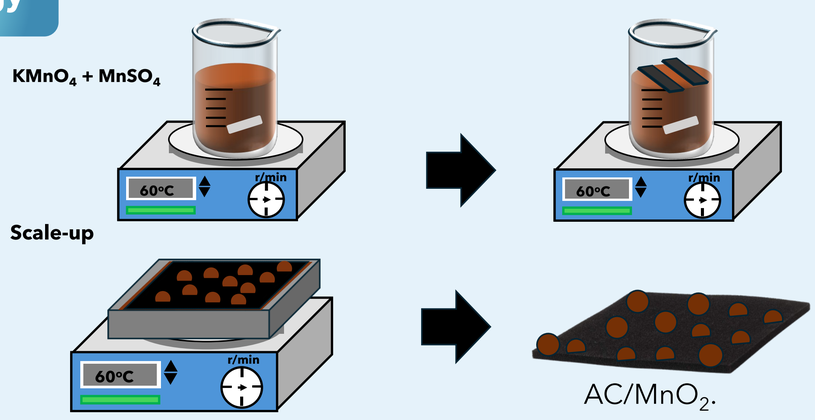
This study presents the development of a manganese dioxide (MnO_2) catalyst designed for ozone decomposition. MnO_2 was synthesized on activated carbon filter sheets via a precipitation process. The crystal structure and morphology of the synthesized MnO_2 were characterized using X-ray diffraction (XRD) and scanning electron microscopy (SEM). The results revealed that the synthesized MnO_2 exhibited a well-defined crystalline structure with a needle-like morphology. The catalytic performance of the material was evaluated through the decomposition of ozone generated by an electrostatic precipitator (ESP), a common source of ozone emissions in industrial processes. Experimental results demonstrated that the catalyst effectively reduced ozone concentrations, highlighting its potential for application in air pollution control.

Introduction

Ozone is a toxic gas that forms from volatile organic compounds (VOCs) such as household paint, fuel, and combustion byproducts from industrial processes. When VOCs are released into the atmosphere, they can react with nitrogen oxides (NO_x) in the presence of sunlight, leading to the formation of ozone, which is harmful to living organisms. Additionally, electrostatic precipitators (ESPs), commonly used for dust removal in industrial processes, have been identified as a frequent source of ozone generation.

The World Health Organization (WHO) has reported that an ozone concentration of 51 ppb can cause respiratory issues, such as asthma, and lead to long-term health effects upon exposure. To mitigate ozone pollution, manganese dioxide (MnO_2) has been utilized as a catalytic material for ozone decomposition. MnO_2 can be synthesized into various crystal structures, each possessing distinct specific surface areas and different levels of ozone decomposition efficiency. Furthermore, MnO_2 catalysts serve as cost-effective catalysts for ozone removal.

Methodology



$KMnO_4$ + $MnSO_4.H_2O$ as precursors with a molar ratio of 2:3.

Dissolved in 50 mL DI.

Add the activated carbon sheet and stir for 2 hours at 60°C.

Washing with DI to neutral.

The products were dried at 80°C.

AC/MnO_2.

Conclusion

MnO_2 was successfully synthesized through a precipitation process. XRD analysis confirmed that the synthesized MnO_2 possessed a tetrahedral crystal system. Additionally, MnO_2 was successfully fabricated on Activated Carbon (AC) sheets. Morphological analysis using SEM revealed a needle-like morphology and well-dispersed on the AC sheet. Ozone decomposition tests demonstrated that the MnO_2 material effectively reduced ozone concentrations from 123 ppb to 31 ppb, highlighting its high efficiency in ozone removal.

Results and Discussion

Crystal Structure.

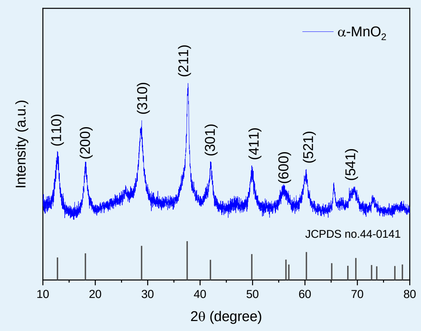


Fig. 1 XRD pattern of the synthesized powder was indexed as a α-MnO_2 with a Tetragonal structure.

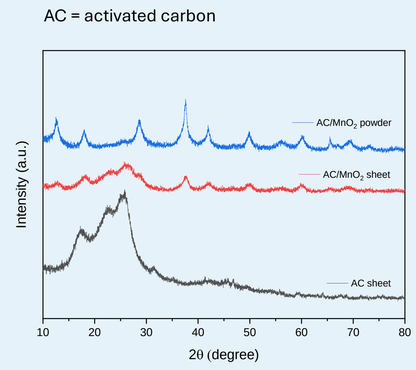


Fig. 2 XRD patterns of the AC/MnO_2 sheet represents MnO_2 deposited on the AC sheet, which retains the crystalline structure of α-MnO_2. When compared to the AC sheet, this confirms the presence of MnO_2 crystals on the AC surface.

Morphology

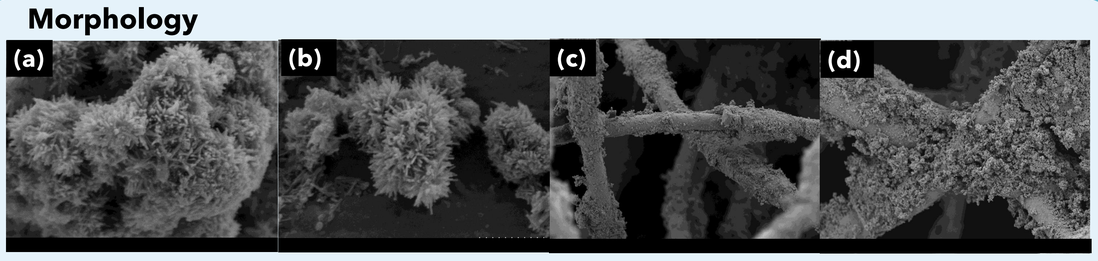


Fig. 3 SEM images of MnO_2 (a) and (b) reveal a needle-like morphology, while (c) and (d) visualize the adhesion of manganese dioxide onto activated carbon sheets.

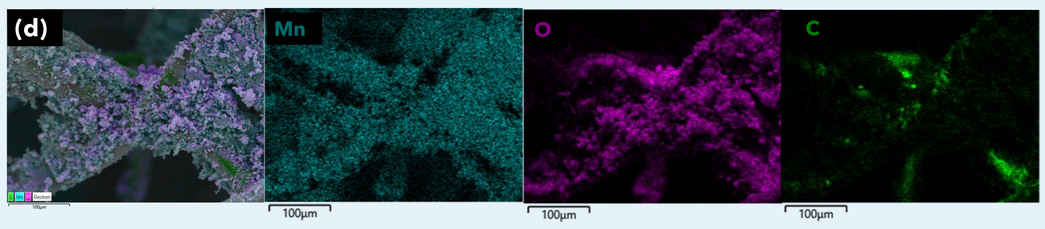


Fig. 4 Elemental mapping of Mn, O and C, respectively.

Decomposition of O_3

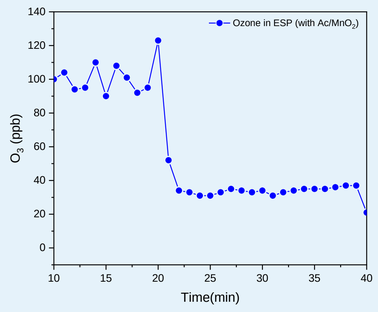


Fig. 5 Ozone concentration at the ESP outlet.

AC/MnO_2.

Ozone decomposition in the ESP was evaluated under a low airflow rate of 0.067m^3/s.

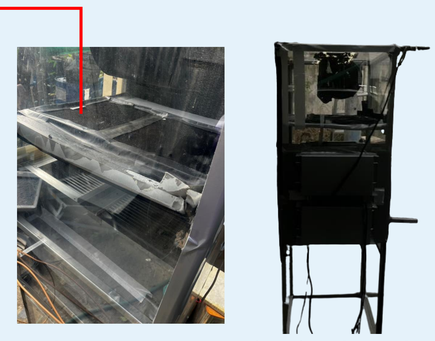


Fig. 6 An ESP setup equipped with AC/MnO_2 filter sheets for ozone decomposition.

Catalytic O_3 Decomposition Mechanism.

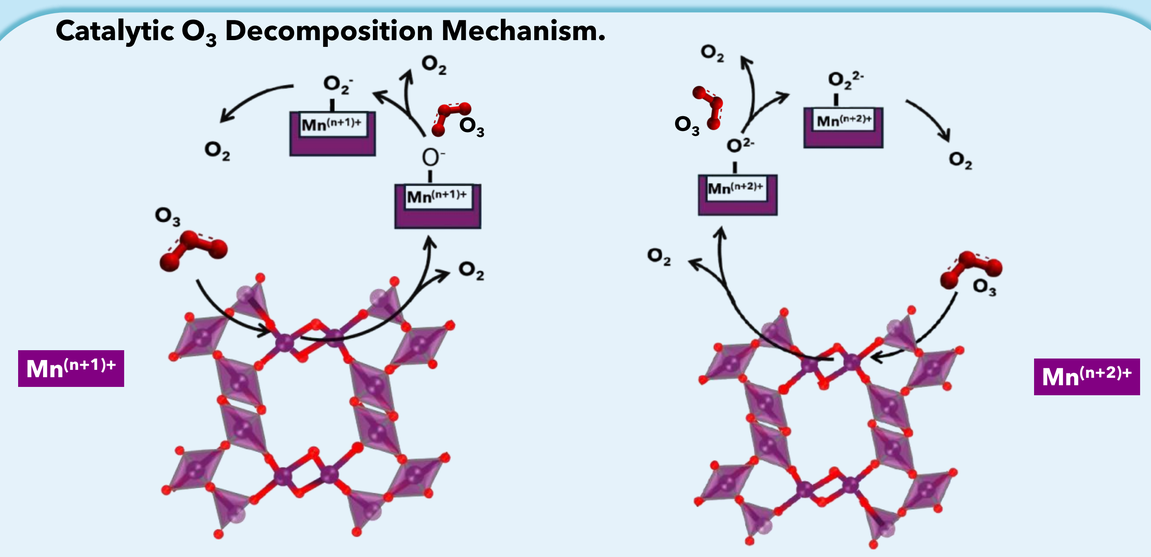


Fig 7. Proposed reaction mechanism of O_3 decomposition on transition metal oxide.

References

[1] L. Chen, Y. Liu, X. Fang and Y. Cheng, *J. Hazard. Mater.*, **2021**, *409*, 125020.
[2] Y. Zeng, R. Xie, J. Cao, Z. Chen, Q. Fan, B. Liu, X. Lian and H. Huang, *Chem. Eng. J.*, **2020**, *388*, 124219.
[3] T. Batakliev, V. Georgiev, M. Anachkov, S. Rakovsky and G. E. Zaikov, *Appl. Catal. A: Gen.*, **2018**, *562*, 16855.

Acknowledgments

The authors express their appreciation to Assoc. Prof. Dr. Chamnan Randorn, lab members, the Department of Chemistry, Faculty of Science, and the Department of Mechanical Engineering, Faculty of Engineering Chiang Mai University for their support and research facilities.